Prototype CMS Pixel Luminosity Telescope (PLT) at MTest

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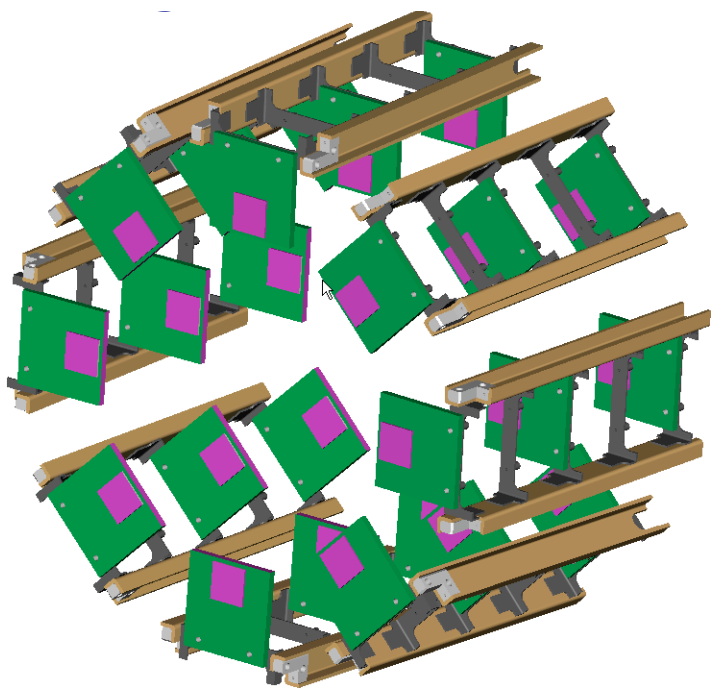
The Pixel Luminosity Telescope (PLT)

- Dedicated stand-alone luminosity monitor for CMS
  - ➡ independent of CMS trigger, other detector components
- Simple device stable over lifetime of CMS
- Precision measure of relative bunch-by-bunch luminosity
  - ➡ statistical precision of 1% in real time (a few seconds)
- Absolute luminosity calibration on:
  - ➡ electroweak process (≈ 5%)
  - ➡ Optical Theorem and forward scattering (≈ 2%)
  - ➡ QED process (≈ 1%)
- Small systematic errors
  - ➡ designed to be below 1%
  - ➡ linear over full range of luminosity
- Self monitoring and calibrating
  - ➡ backgrounds
  - ➡ efficiency

PLT Basic Design

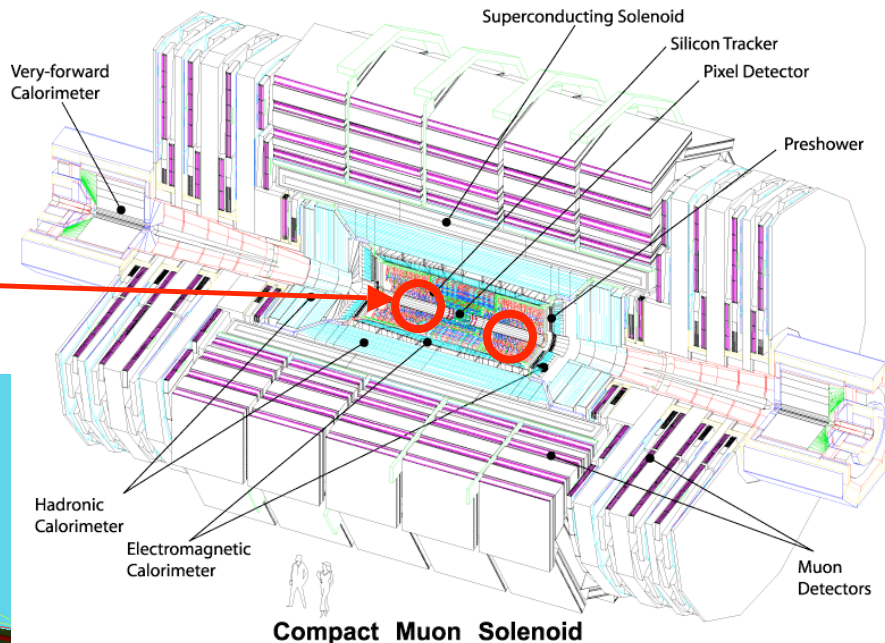
- Telescope Arrays
  - eight telescopes per CMS end
  - location: r ≈ 5 cm, z ≈1.75 m
- Telescopes
  - three planes
  - total length 7.5 cm
- Telescope Planes
  - diamond pixel sensors
  - active area 4.0 mm × 4.0 mm
  - bump-bonded to PSI46v2 pixel ROC

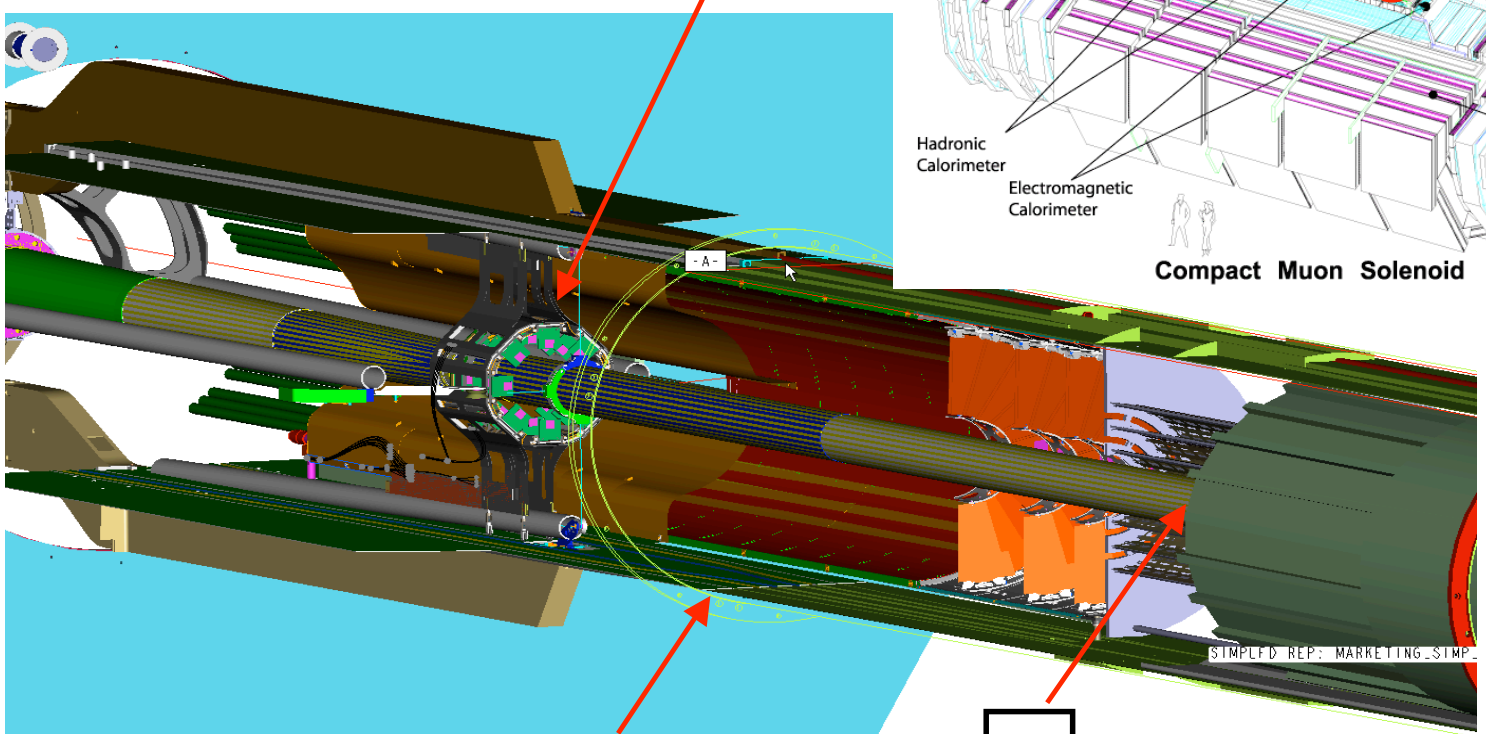


- Measure number of 3-fold coincidences in each bunch crossing (40MHz) using fast-or outputs of the PSI46 pixel chip
- Readout full pixel hit information of each plane at 1 to 10 kHz

Location of PLT

- End of Be section of beam pipe (~ 1.7 m from IP)
- Just outside of beam pipe (~ 5 cm from beam line)

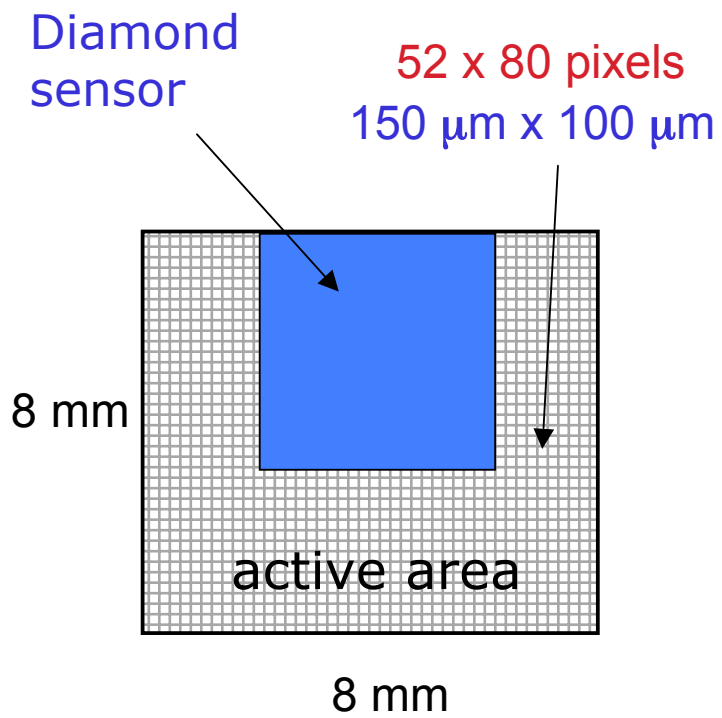




CMS Pixel Readout Chip

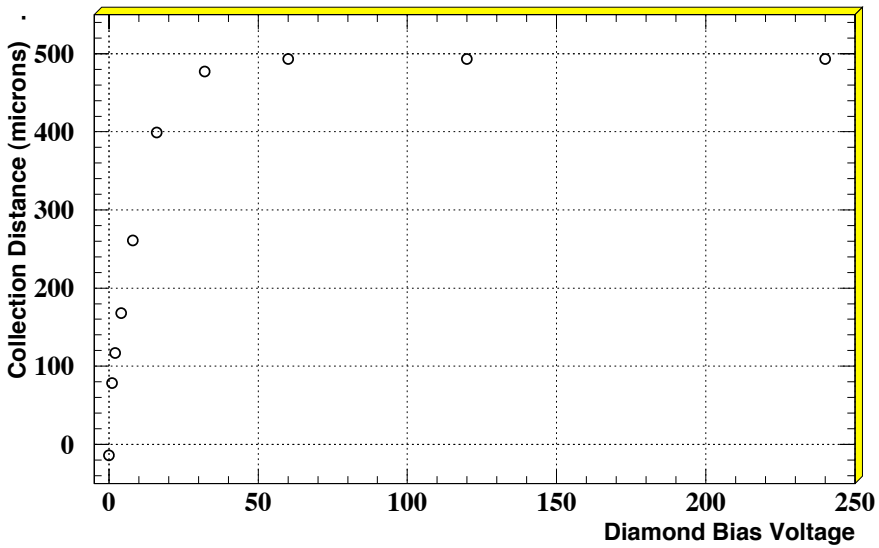
CMS PSI46 pixel chip has “fast” multiplicity counting built in

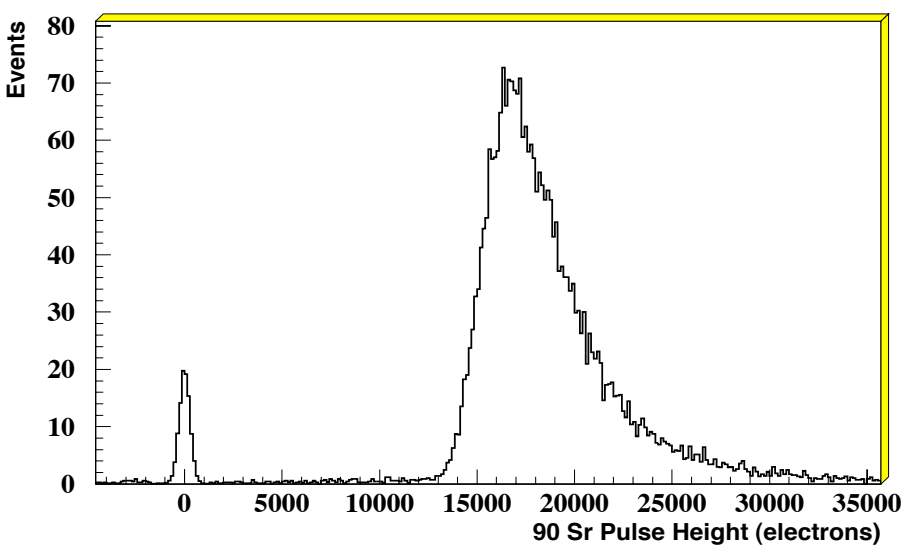
- Double column architecture
- Fast-Or output level
  - 0, 1, 2, 3, ≥4 double column hits
  - each bunch crossing
- Individual pixel thresholds adjustable
- Individual pixels can be masked
- Full pixel readout
  - address and pulse height of hit pixels
  - every L1 trigger

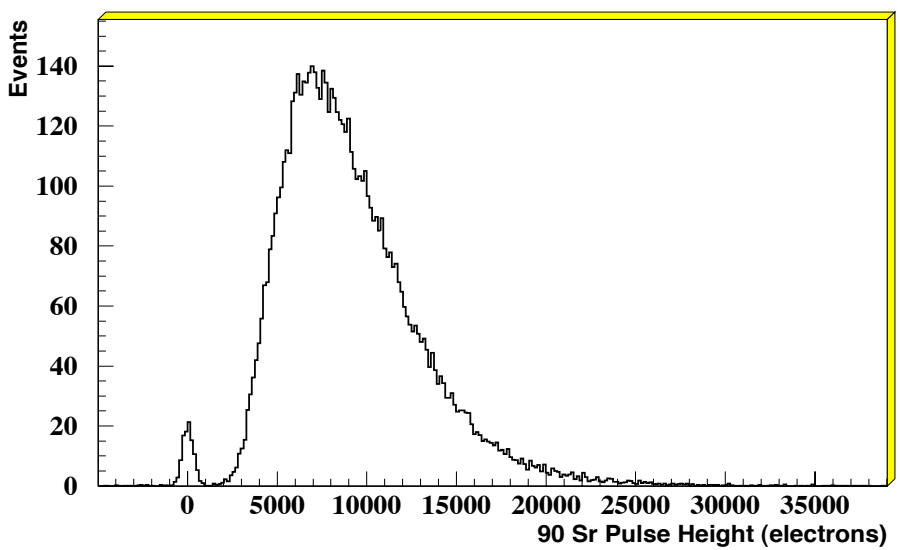


Diamond Sensors

- Radiation hard (few × 10^{15} p/cm^2)
- No need for cooling
- Full charge collection < 0.2 V/μm
  - ➡ 18,000 e$^-$ signal for 500 μm diamond
  - ➡ Landau 60% narrower than for Si
- Pulse height well separated from pedestal
  - ➡ compare poly crystalline diamond

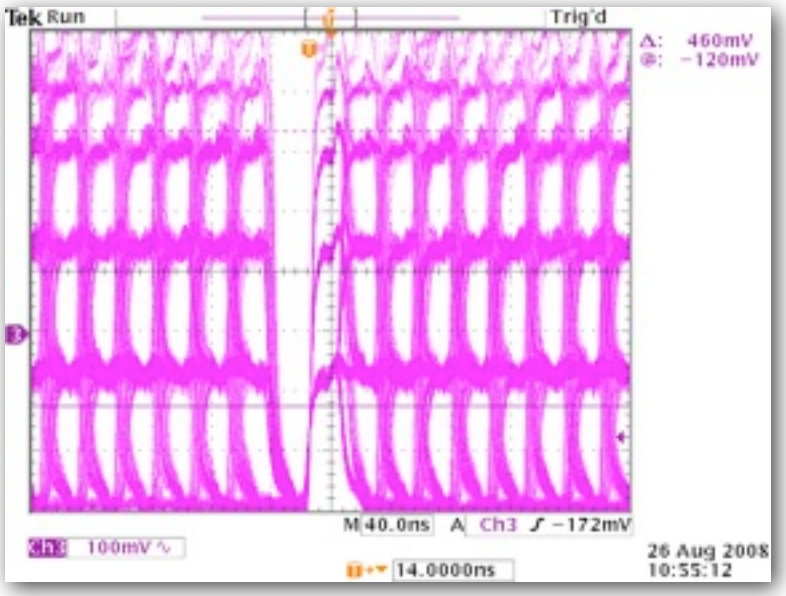


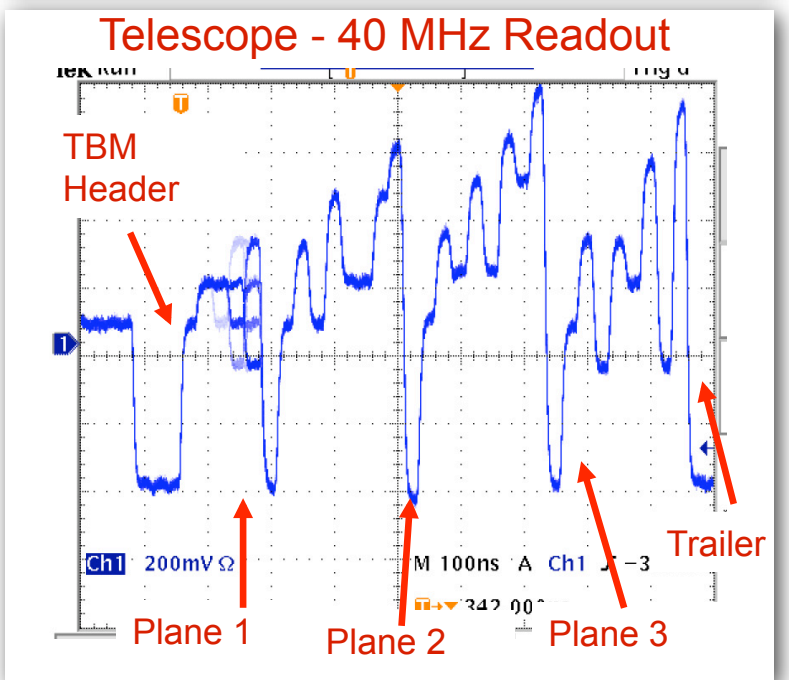




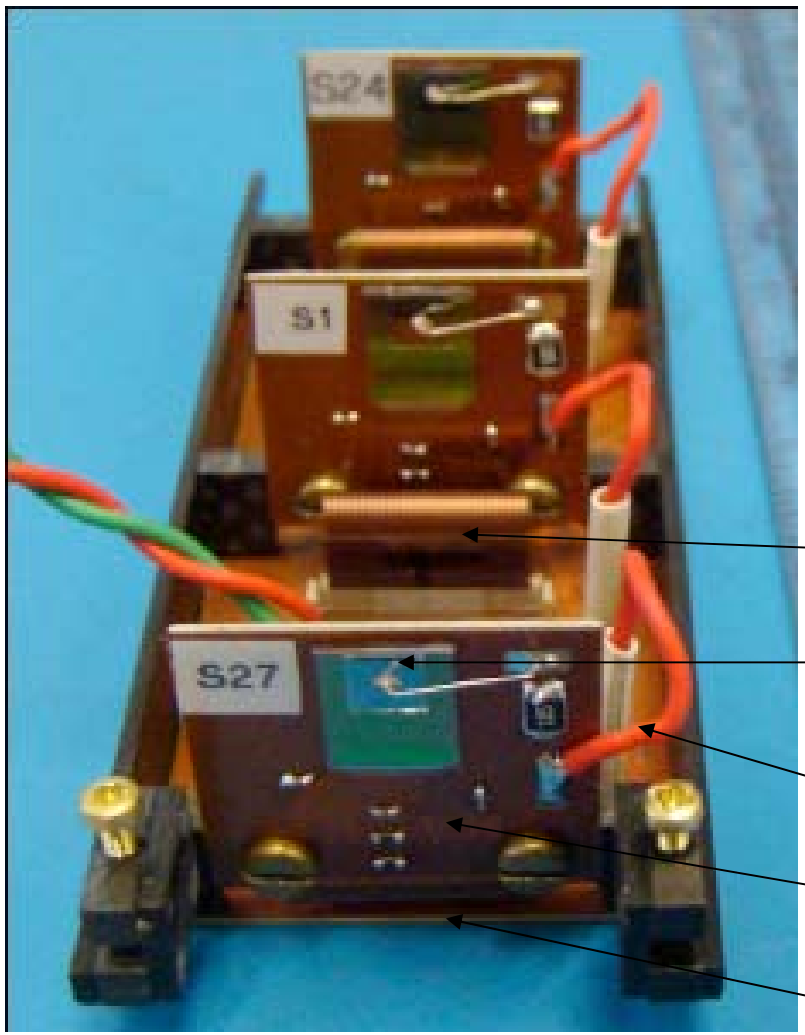
Two Complimentary Readout Modes

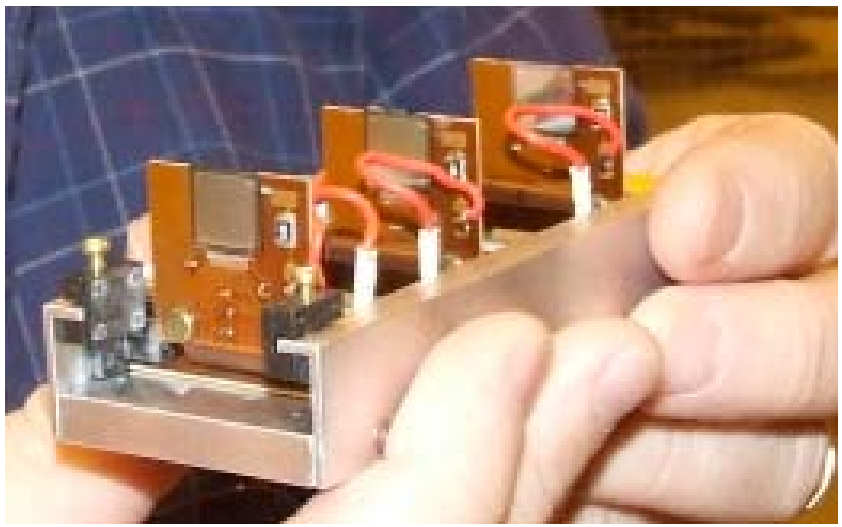
- Fast Or Output
  - every bunch crossing (40 MHz)
  - level → number of double columns hit
  - bunch-by-bunch luminosity
  - abort gap particles
- Full Pixel Readout
  - 1 kHz to 10 kHz rate
  - hit pixel addresses and pulse heights
  - powerful diagnostic for fast hit output mode
  - corrections for accidentals and overlaps
  - pixel efficiencies
  - IP centroid measurement
  - beam halo





Telescope





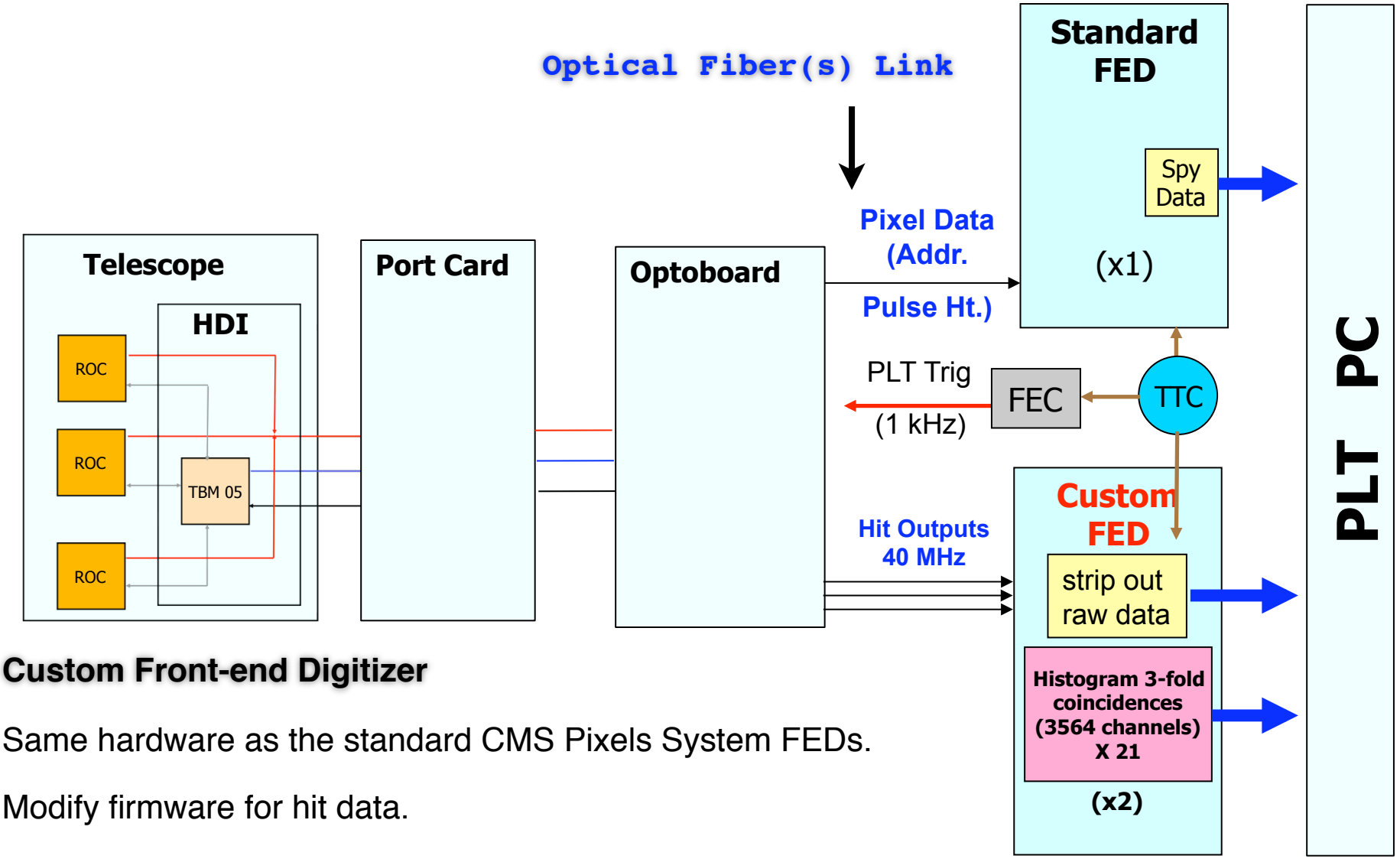
Pig tails

diamond detector
bump bonded on **PSI46 ROC**

Bias HV

Hybrid board

HDI (4 layer flex circuit)
-TBM (chip communication, readout)
- PLT driver chip (amplifies analog FO)
- low/high voltage distribution



Custom Front-end Digitizer

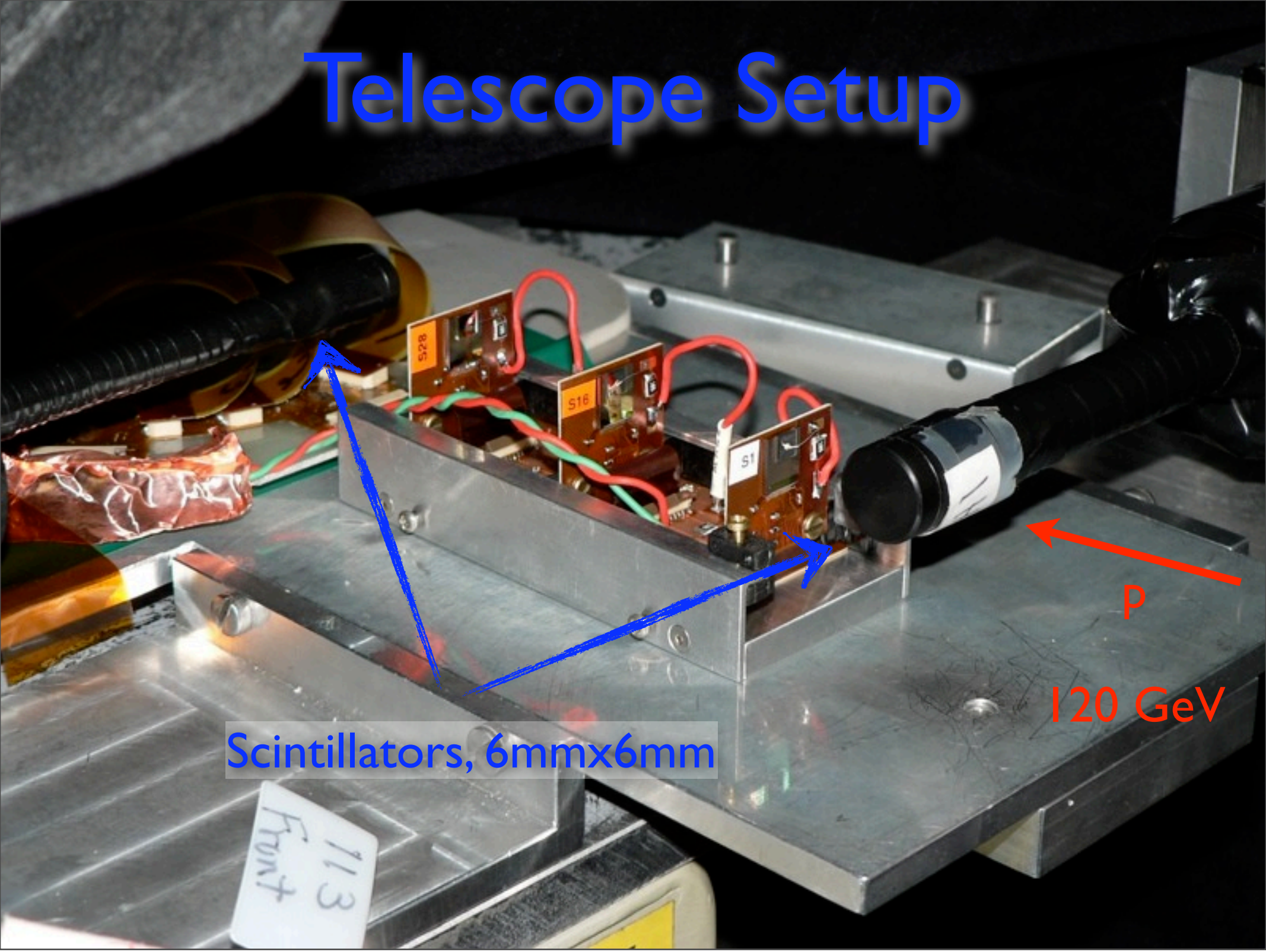
- Same hardware as the standard CMS Pixels System FEDs.
- Modify firmware for hit data.
- Produce 3-fold coincidence for each telescope
- Maintain histogram for each telescope (one entry for each 3564 crossings per orbit)
- Strip out hit data for comparison w/ PLT pixel data in response to TTC trigger , include bunch crossing number.

Telescope System Test

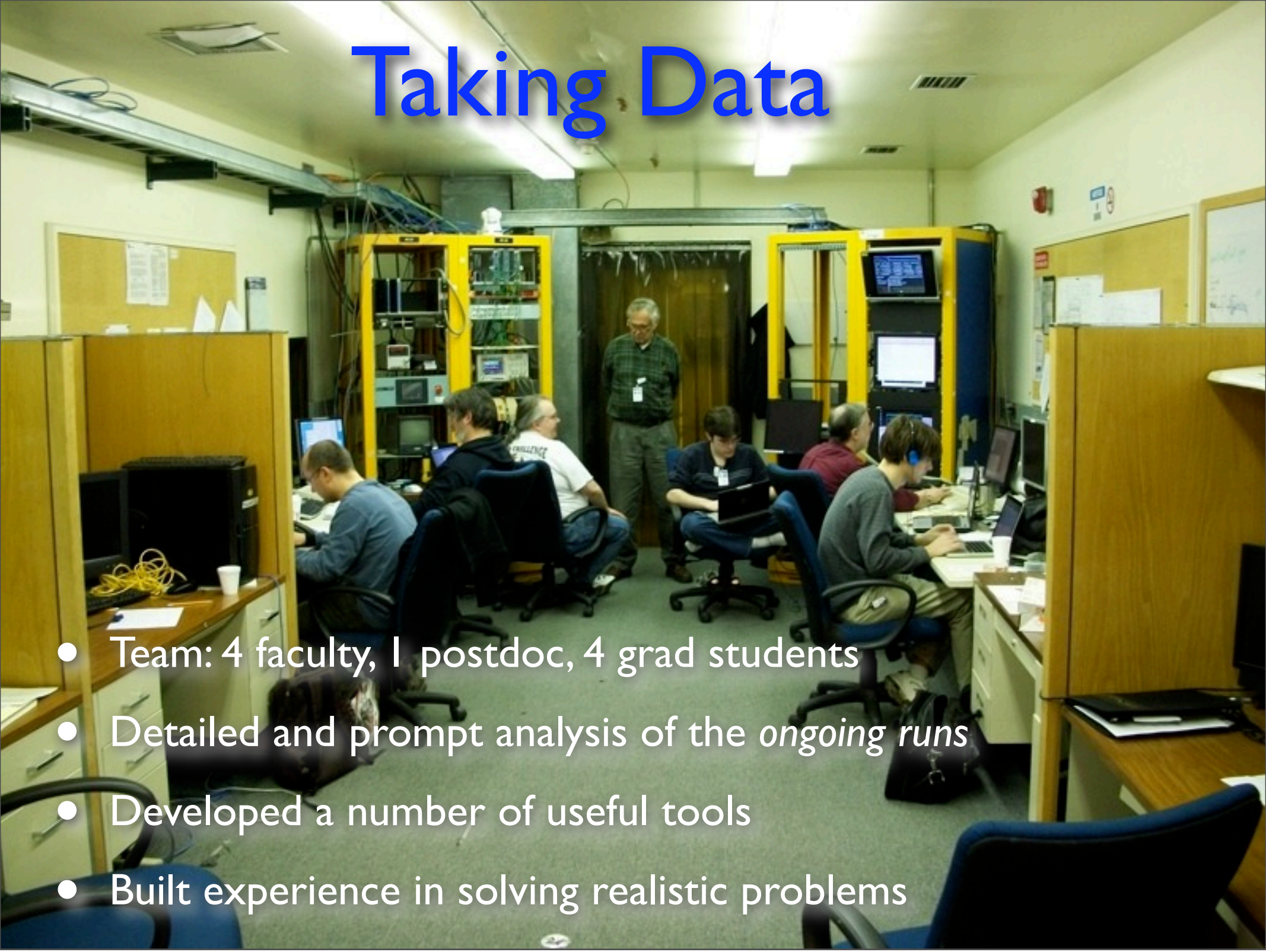
- Optical Readout
- Configuration and *in situ* detector calibration&trimming
- Prompt analysis for immediate feedback.

- 120 GeV proton beam (*6am - 4pm*)
- 3mm by 10mm beam profile
- 4sec/min/spill, 5k trigs/min
- 0.7 M triggers

Telescope Setup

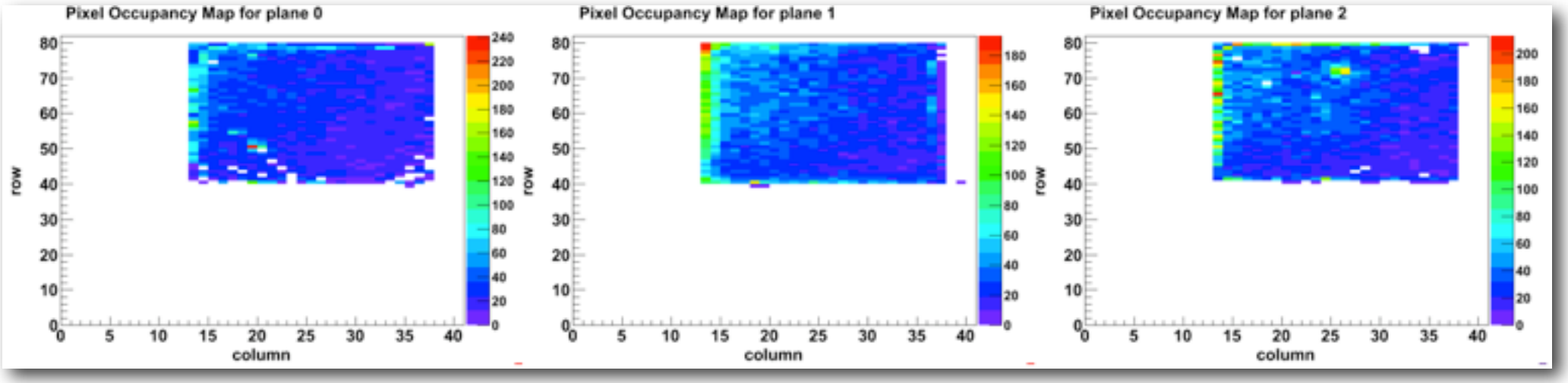


Taking Data



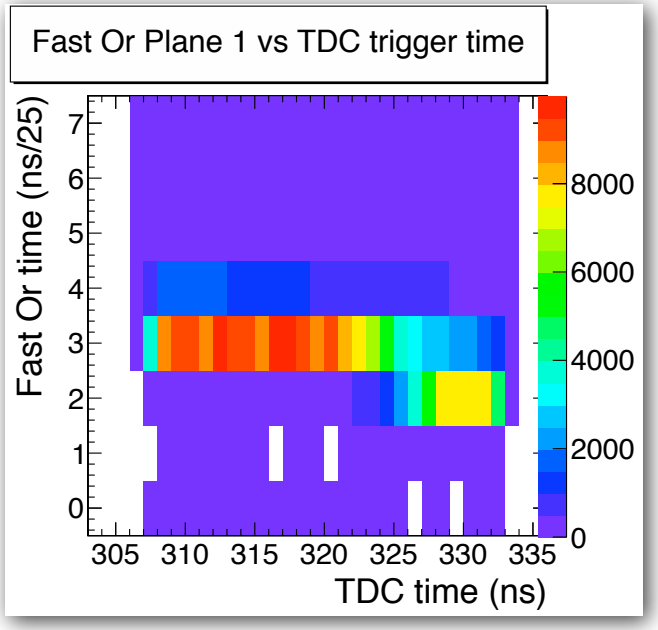
- Team: 4 faculty, 1 postdoc, 4 grad students
- Detailed and prompt analysis of the *ongoing runs*
- Developed a number of useful tools
- Built experience in solving realistic problems

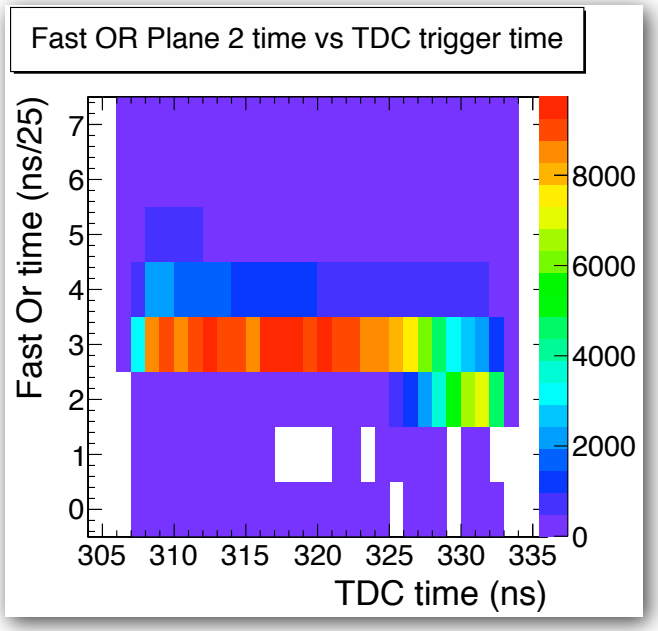
Pixel Yields

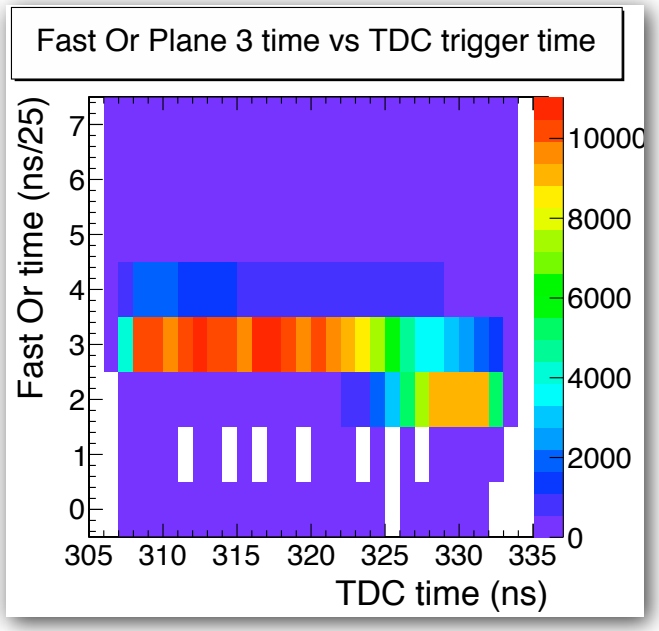


- Pixels at the boundary have different yields and charge collection and excluded from the analysis
- Noisy pixels could be masked out if they could not be trimmed out

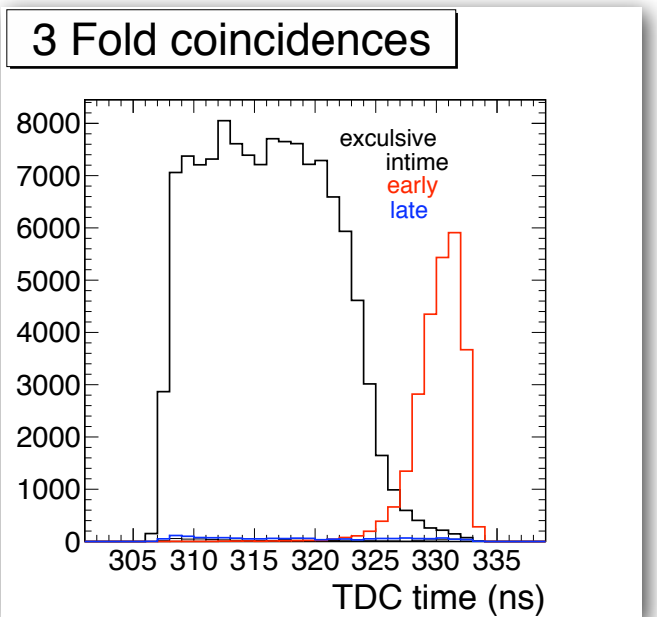
FastOR vs TDC





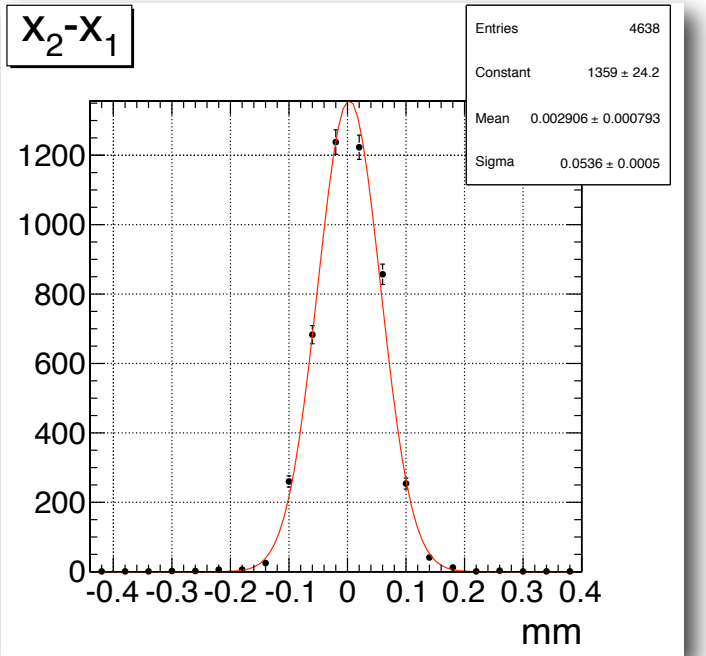


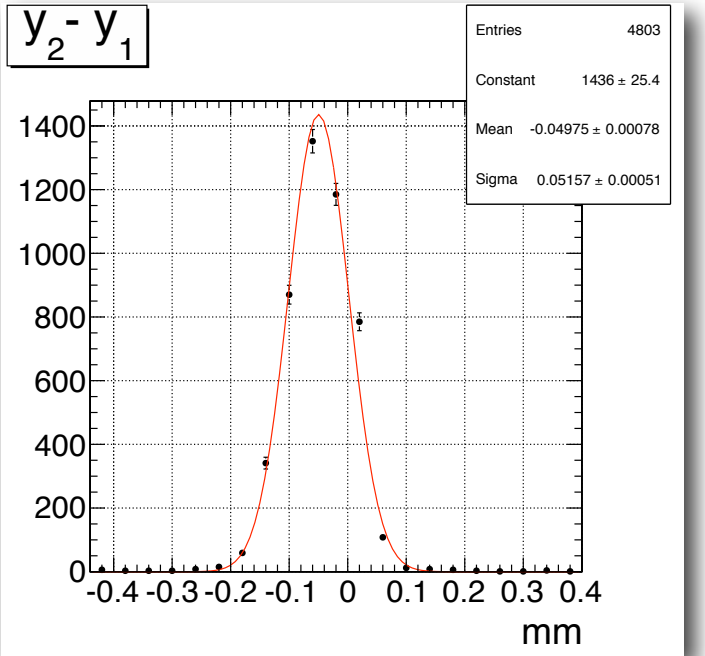
- Can determine TDC timing for triple intime coincidence and remove early fastor's
- Late coincidences contribute to the luminosity uncertainty

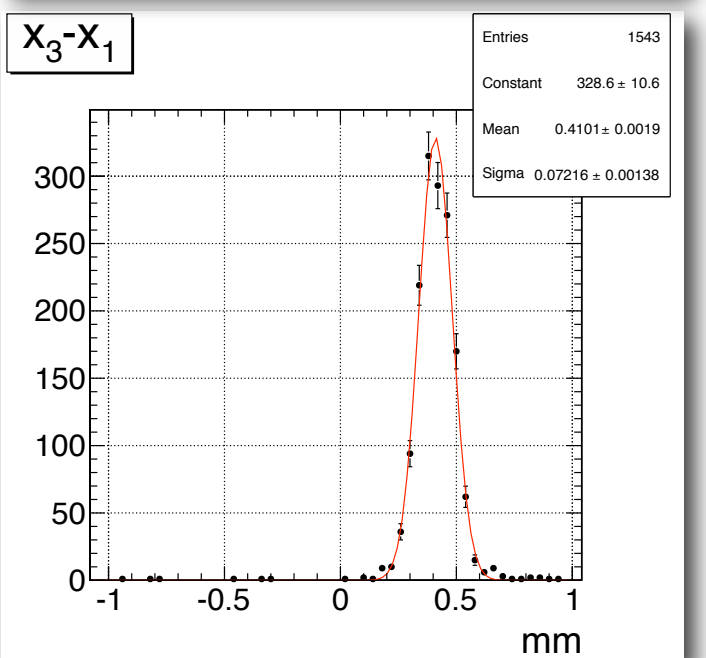


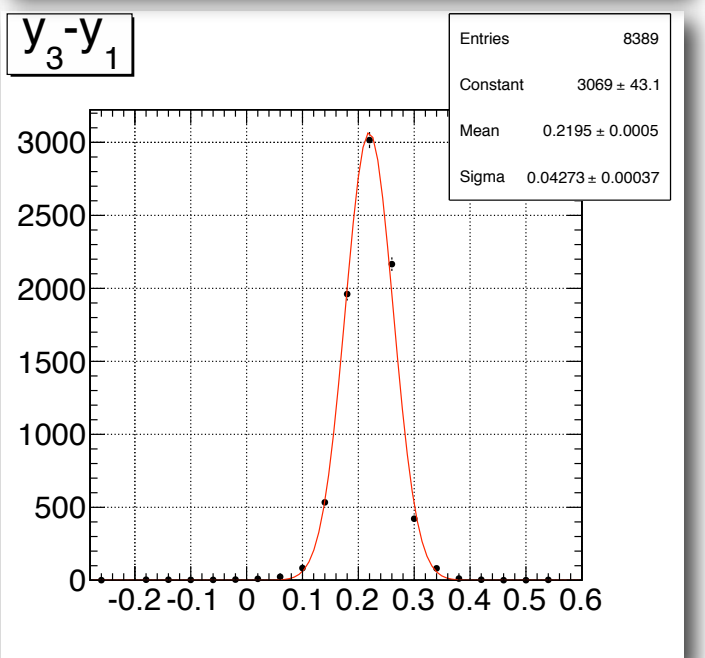
Alignment

- Relative plane to beam alignment
  - plane 1 to 2
    - 30um in x
    - 50um in y
  - plane 1 to 3
    - 410um in x
    - 220um in y



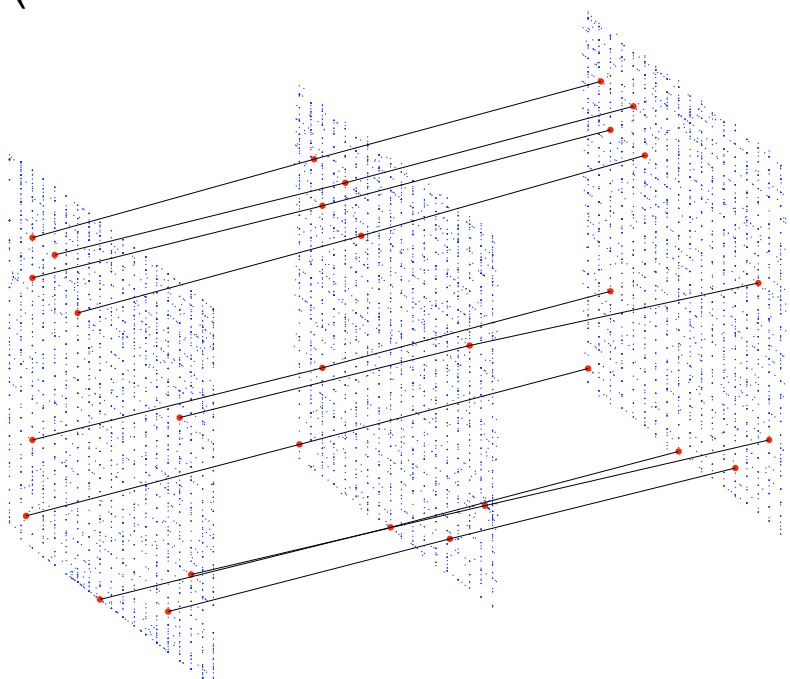




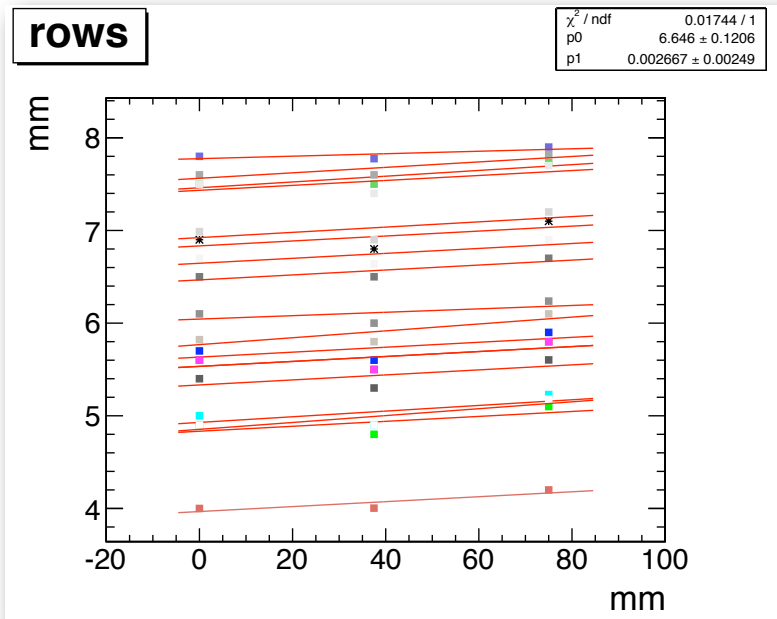


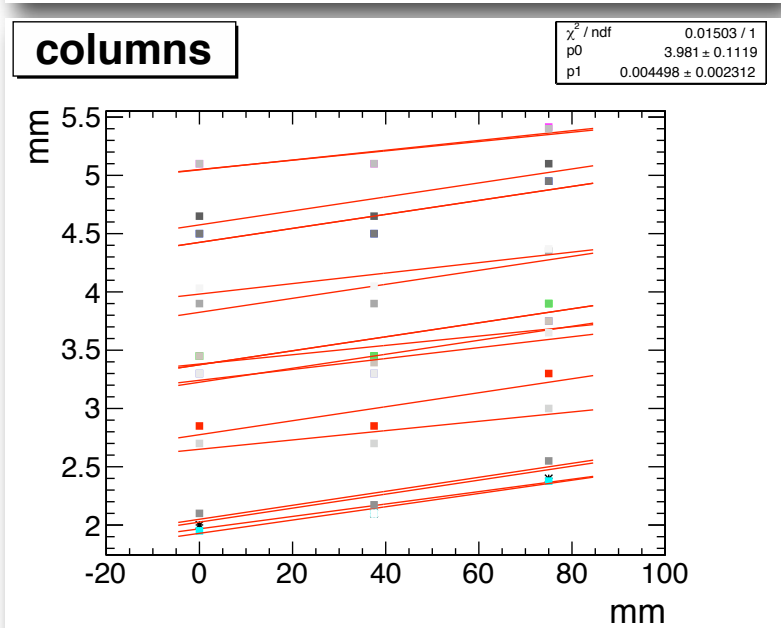
Tracking

- Define cluster: group of neighboring “hit” pixels
- Define cluster position: center of gravity
- Correct for relative plane rotation
- Correct for relative plane offset
- Select events with one and only one cluster in each plane (>90% of events with hits in all three planes)



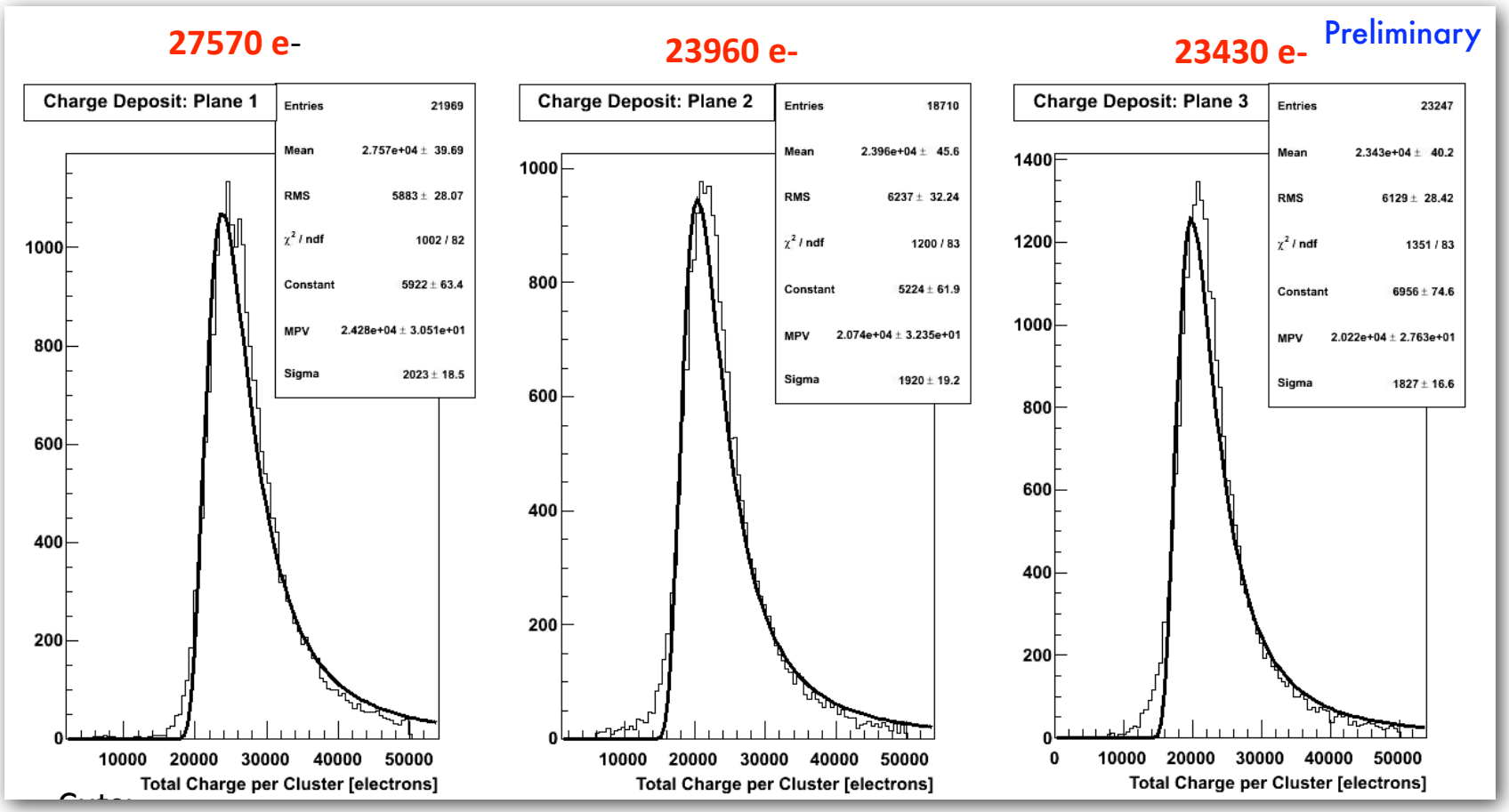
RD09





Pulse heights

- Require single cluster in all three planes
- For Plane c, require hit in regions of Planes a and b such that track is certain to pass through fiducial region of Plane c
- Plot pulse height summed over cluster



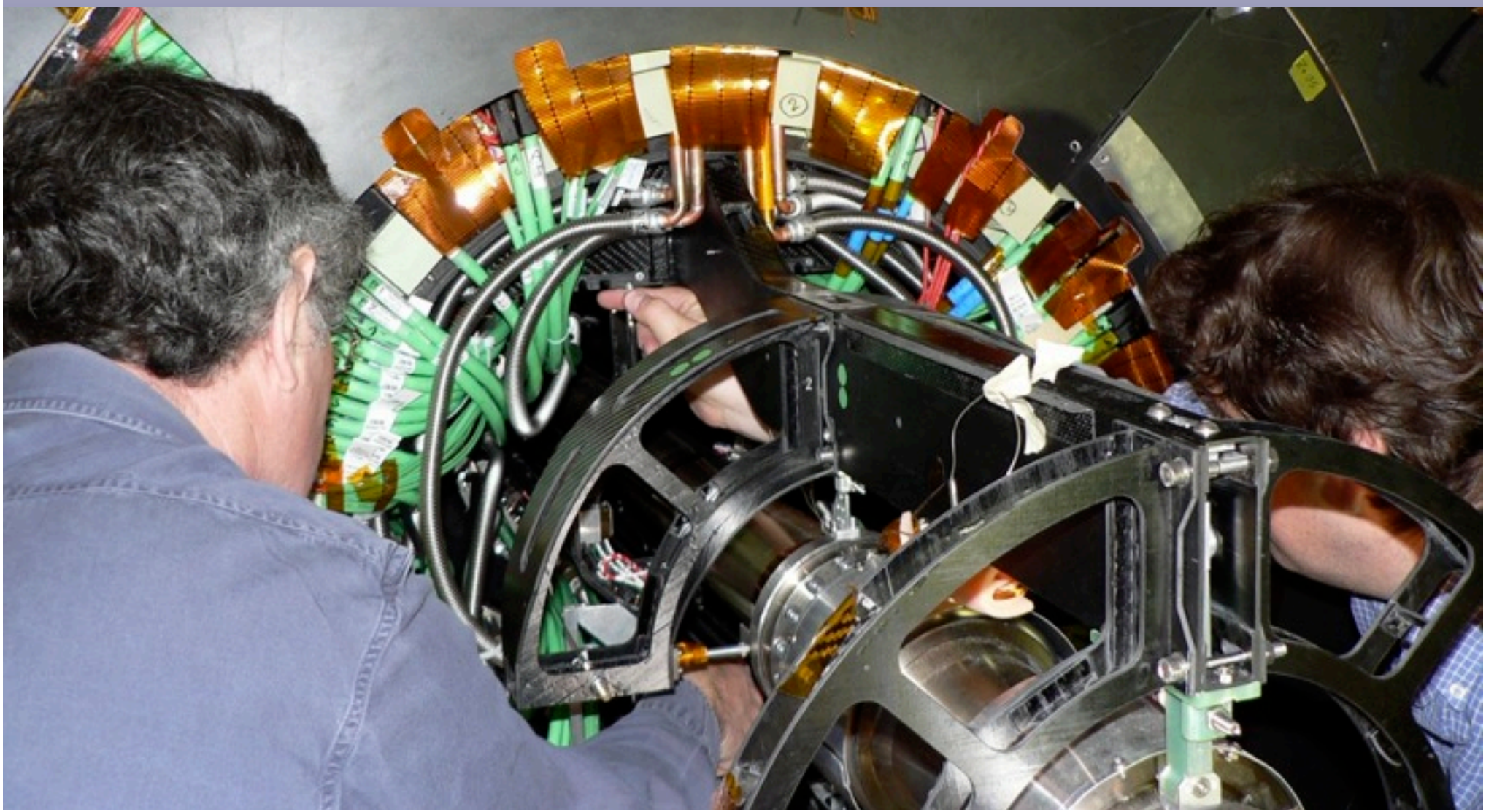
Conclusions

- A lot of help from Fermilab w/ beam test logistics!
- Successful test of optical readout of three-plane prototype PLT telescope
- Ongoing analysis of test beam data
  - ➡ Study fast-or timing
    TDC of trigger and clock
- The prototype meets all design requirements
- Pulse height for high energy protons: ~ 23k e^-
- Pulse heights well above pixel threshold range
- Tracks readily and clearly reconstructed
- Rapid alignment (translation and rotation) of planes with beam

Schedule/Future Plans

- Passed CMS Engineering Design Review last fall
- Ongoing analysis of the test beam data
- Irradiated telescope planes ~ full LHC lifetime (2×10^{15} p/cm^2)
  - ongoing analysis
- In production mode
  - characterization and testing of 48+ planes w/ Sr90
- PLT ready for installation in CMS by mid-fall 2010

On course for PLT installation during 2010-2011 shutdown



Backup

Data Acquisition